

## **Bridging Orbit and Classroom: SatNOGS and CubeSatSim Activities**

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#### **Abstract:**

This paper addresses the challenge of interpreting satellite telemetry data and relating it to real-world satellite behavior. It introduces a powerful synergy between SatNOGS, a global open-source network offering free access to over 12 million satellite data downloads, and the CubeSatSim (CSS), AMSAT's low-cost satellite simulator.

SatNOGS enables students to "adopt" on-orbit CubeSats, providing the experience of being a satellite operator by scheduling downlinks and monitoring dashboards. To overcome the difficulty in interpreting this real-world telemetry, the CubeSatSim offers a hands-on, controlled environment. Students manipulate the CubeSatSim to directly understand how sensor data reflects solar panel performance, orientation, spin rates, and radio communications. This practical experience enhances their ability to interpret SatNOGS dashboards, demystifying the conversion of "waterfall signals into bits" and "bits into data". Together, SatNOGS and CubeSatSim provide both real-world data and practical understanding of telemetry data.

#### **Introduction:**

Every year, dozens of educational institutions place CubeSats into orbit. Many more institutions and students aspire to join their ranks but cannot due to costs and limited launch availability. However, these students can gain the knowledge and experience of building and operating a CubeSat by assembling AMSAT's CubeSat Simulator and by "adopting" an existing on-orbit CubeSat on SatNOGS.

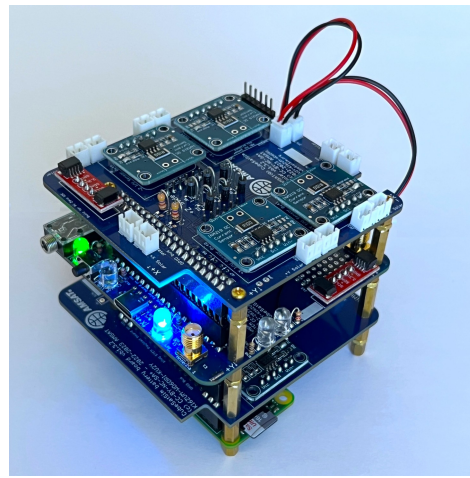
AMSAT's CubeSat Simulator (CSS) is an inexpensive, fully functional CubeSat, but is not space-worthy. It contains most of the components of a 1U CubeSat: frame with solar panels on each side, rechargeable batteries, power monitoring, flight computer, UHF/VHF radio board, camera, payload computer, inertial measurement unit (IMU) and environmental sensors. It is available as a no-solder kit that can be assembled by students in less than a day.

The CSS transmits operational telemetry data typically sent by all CubeSats: power output (voltage and current) of each solar panel, battery power, IMU data, sensor data, general health of each subsystem. This data is received using an inexpensive Software Defined Radio (SDR) dongle connected to a Raspberry Pi or a Windows system. The raw data is interpreted in real time and displayed by an AMSAT developed program: FoxTelem.

AMSAT has developed a series of hands-on educational activities for the CSS and FoxTelem to teach students how to read telemetry data and relate it to satellite performance.



Assembled CubeSatSim



Internal 4-board stack

SatNOGS is a global network of open-source ground stations operated by educational institutions, hobbyists and space enthusiasts. These stations receive data from orbiting educational satellites and upload the data to an open access database that as of September 2025 contained more than 12 million observations from 2300+ satellites. This data is available to anyone via the SatNOGS website. In addition to raw and decoded data, dashboards have been developed for some satellites to provide visual access to operational data.

Much of the operational data contained within SatNOGS is the same as reported by the CSS. And SatNOGS dashboards are similar in function to FoxTelem graphs.



A minimal SatNOGS ground station, consisting of a Raspberry Pi, SDR dongle and dipole antenna, can be built for less than \$150US. Software and detailed instructions are available on the wiki found on the SatNOGS website.

Ideally the antenna is outdoors and elevated, but as this station shows, a functional station can be indoors as long as it has a clear view of some portion of the sky. Once the station is on-line and registered, students can schedule observations (downloads) on multiple SatNOGS stations around the globe.

By selecting a dozen geographically spaced stations, they can establish their own global virtual down-link network.

## Adopt a Satellite:

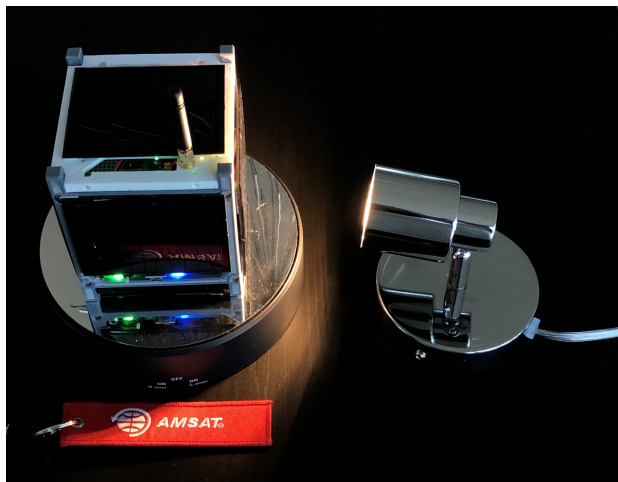
Once a CubeSat is on-orbit, its operators need to continuously monitor its health and collect scientific data. By “adopting” an existing, on-orbit CubeSat, students have the experience of being a satellite operator without the expense and risk of launching their own CubeSat. Using published information, students learn about their “adopted” CubeSat, its mission and orbital path, communications protocols used and data returned, etc. By using SatNOGS to schedule data downlinks across their “virtual network” and monitoring the CubeSat’s dashboard over a 1 to 4 week period, students learn about the CubeSat’s communications, operations and performance. As well as experiencing some of the activities of a satellite operator.

## Using the CSS to Understand SatNOGS data:

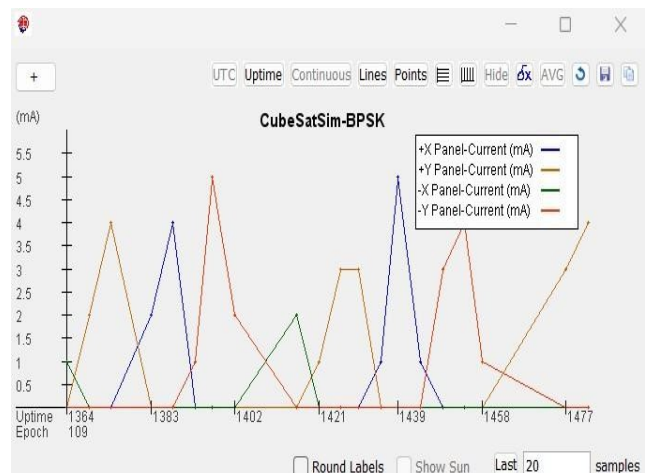
One challenge from viewing SatNOGS telemetry is relating it to the satellite’s orientation and behavior in space. It’s a dynamic environment of constantly changing data. It may be difficult to interpret data abnormalities.

The CSS provides a controlled, hands-on environment to collect data from a CubeSat. The CSS can be held stationary for an extended period of time allowing students to note readings from the solar panels and IMU. Then it can be rotated 90 degrees showing students how the readings change with position and orientation. After repeating this exercise with multiple positions on each of the three axes, students can construct a mental image of how telemetry data relates to satellite orientation.

Students can take the CSS in hand and simulate a tumbling CubeSat. Placing the CSS on a rotating turntable in front of a bright light source (or better in outside sunlight), students can use FoxTelem to plot how the solar panels output change with each rotation. And by slowly moving a cardboard panel between the CSS and light source, students can simulate the CSS entering and leaving eclipse.



CSS on turntable



Resulting FoxTelem plot

The CSS software also has a simulated telemetry mode in which the CSS transmits nominal data along with data indicative of a failed component. Students are challenged to determine the cause of the failure.

The knowledge gained from these CSS activities enable students to better understand the telemetry from their “adopted” satellite.

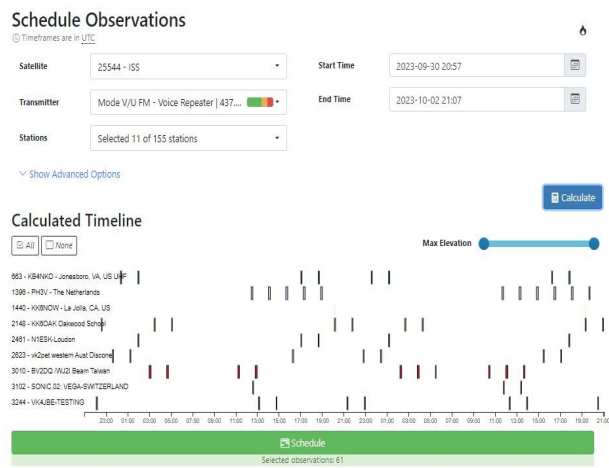
### How to Adopt a Satellite:

Where does one start? While this can be done as an individual exercise, it’s better (and less work) as a group exercise, either as a classroom or space club activity.

First explore the SatNOGS.org website. Then assemble a minimal ground station and start scheduling observations on your station. Once your station is on-line, look at the SatNOGS network map and schedule simultaneous observations over several other stations, some nearby and some far away.

Assemble students into teams of 3 to 5. Each team picks a satellite for adoption. Ideal adoptees have a dashboard, are currently active and successfully received by numerous stations, have more than 6 months of on-orbit data available, and documentation is readily available via the owner’s website.

Each team learns as much as they can about their satellite. They schedule downlinks across their global virtual network, monitor received data and compare data to historical data over a 2 to 4 week period. At the end, they present their research and findings to the group. entering and leaving eclipse.



Scheduling downlinks



Typical dashboard

For real excitement, students can adopt a satellite before launch. SatNOGS often publishes information on their forum about ride-share missions pre-launch. Students can often watch SpaceX ride-share deployments in real-time on YouTube or X. CubeSats typically start transmitting soon after deployment. Dozens of SatNOGS station owners may compete for bragging rights to be the first to receive the signal. It can be a fun and involving exercise for students, but frustrating. Expect many observations with no signals.

### In Conclusion:

This combined approach offers the **hands-on experience of building and understanding a CubeSat** (via CubeSatSim) and **access to real telemetry with the experience of being a**

**satellite operator** (via SatNOGS), all without launch risks. This powerful framework fosters deep engagement with space science and engineering. For more information, visit [SatNOGS.org](http://SatNOGS.org), [CubeSatSim.org](http://CubeSatSim.org), or [Amsat.org](http://Amsat.org).